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Review

The dual sustainability of wind energy

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ABSTRACT

Academics, practitioners, and policy makers continue to debate the benefits and costs of alternative sources of energy. Environmental and economic concerns have yet to be fully reconciled. One view is that decisions that incorporate both society's concern with the environment and investors' desire for shareholder value maximization are more likely to be truly sustainable. We coin the term *dual sustainability* to mean the achievement of environmental and financial sustainability simultaneously.

Many experts believe that wind energy can help to meet society's needs without harming future generations. It is clean and renewable. Because the fuel is free it provides the ultimate in energy independence. Wind energy has emerged as a leading prospect, in part, because it is considered by many to be environmentally sustainable.

However, a key question that remains is whether wind energy is financially sustainable without the extensive government support that has helped to create and nurture this growth industry. Using reliable, proprietary data from field research, our analysis employs a capital budgeting framework to evaluate the financial economics of investments in wind energy. We find that because of the convergence of improved technology, greater efficiency, and with the increasing cost of traditional, competing sources such as oil and natural gas, wind energy is close to becoming self-sustaining financially without the extensive federal government support that exists today.

Wind energy can provide the best of both worlds. It is sustainable from an environmental perspective and it is becoming sustainable financially. In short, those companies investing in wind energy will be able *to do well by doing good*. Perhaps the achievement of dual sustainability is true sustainability.

Our research findings and dual sustainability have several interesting and important implications for public policy towards wind energy. All imply that public policy can now be executed in a more effective and efficient manner. In the paper we outline and offer these better and cheaper public policy alternatives for consideration.

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1. Introduction

Academics, practitioners, and policy makers continue to debate the benefits and costs of alternative sources of energy. Wind energy is considered to be sustainable from an environmental point of view, where sustainable is defined as meeting society's current needs without harming future generations [1]. Wind energy is clean and renewable. Because the fuel is free it provides the ultimate in energy independence. Wind energy has emerged as a leading prospect, in part, because it is considered by many to be environmentally sustainable.

However, others note that environmental and economic concerns have yet to be reconciled [2]. One view is that decisions that incorporate society's concern with the environment and investors' desire for shareholder value maximization are more likely to be truly sustainable [3]. We coin the term *dual sustainability* to mean the achievement of environmental and financial sustainability simultaneously.

Because the financial viability of wind energy has not been fully explored, in this article we present an analysis of the financial economics of wind energy and endeavor to determine whether it is sustainable *without* the extensive government support that has helped to create and nurture this growth industry. Using reliable, proprietary data from field research, our analysis employs a capital budgeting framework to address the financial economics of investments in wind energy. We find that because of the convergence of improved technology, greater efficiency, together with the increasing cost of traditional, competing sources such as oil and natural gas, wind energy is close to becoming self-sustaining financially without the extensive federal government support that exists today.

Our research findings and dual sustainability have interesting and important public policy implications. Although public policy towards wind energy in the U.S. can generally be described as a qualified success story, a key question is, what's next? The evidence suggests that public policy toward wind energy can now be executed in a more effective and efficient manner. We offer these better and cheaper policy alternatives for consideration.

2. Theory and background

The public finance literature addresses the role of government participation to initiate and support investments and to reallocate resources when the payoff for private investors is uncertain, when the timing of the payoff is beyond the normal range and when private investors cannot capture all social benefits (e.g. Musgrave [4]). Wind energy appears to be such a situation where, because there are external economies, investments are desirable from the public point of view, but could be unprofitable from the private point of view.

Russo [5] explores the determinants of where and when wind energy projects could be created. His findings suggest that the convergence of natural capital, social and economic influences spur greater investment. The California experience with wind energy is used to illustrate that a convergence of economic and social factors can act in concert with the natural environment to incubate a whole industry. California is often credited with beginning the wind industry in 1980; and by 2006 California had the second largest installed capacity of any state except Texas.

Hall and Vredenburg [6] utilize several case studies, two of which focus on wind power at the energy company Suncor and the electric utility TransAlta in Canada. The authors use an extended view of Schumpeterian creative destruction of technological change. Wind power, although an established technology, can be viewed as destructive to a company's technological competencies. However, if the company handles the impact on its own operations, as well as primary and secondary stakeholders effectively, the new technology can enhance its non-technological competencies, have a positive impact on primary stakeholders and be viewed by secondary stakeholders (society and its concern for environment and future generations) as innovative. This can lead to innovation for sustainable development as illustrated in the two case studies.

Surveys of empirical studies using the structure–conduct–performance paradigm of Industrial Organization Economics demonstrate that competition combined with a modest degree of monopoly power is most conducive to technological advancement (e.g. Scherer and Ross [7]). An optimal blend of competition and monopoly, but with more emphasis on the former than the latter, is best for rapid technical progress. Competition provides multiple sources for ideas as well as pressure from rivals to innovate. Monopoly power allows investors to capture greater than normal profit as the necessary reward for taking risk.

The corporate finance literature suggests that investments in new technology can be viewed in a capital budgeting context. The decision rules are to invest in any project with a positive *Net Present Value* (NPV), and to invest as long as the return on the investment (IRR) exceeds the rate of return on equivalent investments in the capital market (e.g. Scherer and Ross [7]). The rate of return on equivalent investments is approximated by the firm's weighted average cost of capital. Investments with a positive NPV and an IRR greater than the weighted average cost of capital are worth undertaking.

This study uses a capital budgeting framework to analyze investment in wind energy from an investor's viewpoint. Policy makers need to understand this perspective in order to craft the most efficient and effective public policy.

3. Worldwide status of the wind energy industry

Wind energy is a growth industry in the U.S. and worldwide. In 2006, installed capacity in the U.S. grew over 26% to reach a total 11,603 MW (mega watts). Worldwide installed wind capacity increased by over 25% to reach 74,223 MW.[2] Germany was the leader with 20,822 MW, followed by Spain (11,615 MW) and the U.S. (11,603 MW). India (6270 MW) and Denmark (3126 MW) were behind the U.S. Other countries that had reached 1500 MW were China, Italy, UK, Portugal and France. On an installed capacity per capita basis, Denmark was the leader with 576 W per capita, with approximately two and half times the installed capacity of countries in second and third place, Spain (260 W) and Germany (251 W). The U.S. was fifth with 38 behind the Netherlands with 95 W per capita.

The leading providers of wind energy in the U.S. are a diverse group. They include FPL Energy (a subsidiary of Florida Power and Light Group) with 47 wind farms in 15 states; it has a total of 4224 MW, 36% of the U.S. total. FPL is followed by PPM Energy (830 MW), a Scottish power company; MidAmerica Energy (460 MW), a utility company headquartered in Iowa; Caithness Energy (346 MW), an independently owned Independent Power Producer (IPP); and Babcock & Brown (319 MW), an international company listed on the Australian stock exchange with worldwide operations. Other notables include American Electric Power, a large mid-western utility; Shell Wind Energy, headquartered in the Netherlands; and Goldman Sacks, the investment banking firm.

Larger and more efficient wind turbines are being manufactured by the likes of General Electric in the U.S., Siemens in

[2] American Wind Energy Association, http://www.awea.org.html.

Germany, Gamesa Corporacion Technologica/Eolica in Spain, Mitsubishi in Japan and Vestas Wind in Denmark.

States with the most wind energy capacity installed include Texas (2768 MW); California (2361 MW); Iowa (936 MW); Minnesota (895 MW) and Washington (818 MW). The windiest states in the country with the most potential to produce wind energy are in the Great Plains.

4. Public policy

Three decades ago the U.S. Department of Energy set a goal of achieving 5% of wind generated electricity by 2020. Recently the President in collaboration with *The American Wind Energy Association*, the U.S. Department of Energy and the National Renewable Energy Laboratory committed to developing a plan to achieve 20% of the nation's electricity from wind energy by an unspecified date.[3]

Early structural changes in the electric utility industry fostered competition and alternative sources of energy. The *Public Utilities Regulatory Policies Act* of 1978 (PURPA) encouraged alternative energy sources and cogeneration via independent power producers (IPPs). Existing utilities were required to buy electricity from them at avoided cost. Fifty percent of all generating capacity in the U.S. has been provided by IPPs.

The *National Energy Policy Act* of 1992 (NEPA) encouraged competition in the production and sale of wholesale power. NEPA mandated utilities to provide wholesale wheeling (the transmission of large volumes of electricity over long distances) at cost from any electric generating utility or IPP to another utility. NEPA also created the exempt wholesale generator (EWG) form of IPP, and allowed them to be majority owned by investor-owned utilities. EWGs can operate outside the U.S. and compete in foreign markets at the retail level; also foreign companies were permitted to own EWGs in the U.S.

The Federal government provides financial incentives as well. Wind plants are allowed accelerated depreciation for tax purposes over a 5-year period even though their useful lives are 15–20 years. Furthermore, a production tax credit (PTC) is available. It was originally included in the 1992 *National Energy Policy Act* and provided a credit of 1.5 cents per kilowatt hour (kWh) for electricity generated from wind turbines in their first 10 years of operation. The credit has increased to 1.9 cents per kWh with inflation and it was extended to December 31, 2007, by the *National Energy Policy Act* 2005. In December 2006, as part of a tax and trade policy act, Congress extended the credit through December 31, 2008. Payments comparable in value to the PTC are made by the Department of Energy for certain non-taxpaying entities such as municipalities.

At the state level, nearly half the states require that retail suppliers of electricity meet renewable energy portfolio standards and buy renewable energy certificates from owners of wind farms for a certain percentage of electricity they sell. This provides a source of revenue for the wind farms. Furthermore, other middlemen, sometimes called "green-up specialists" can buy the remaining renewable certificates and sell them to electricity consumers who want more electricity produced by renewable sources. For example, through National Grid in Massachusetts, consumers can elect to pay 2.0–2.4 cents per kWh more than for electricity produced by fuel mixes of small hydro, biomass, wind and solar. Such arrangements can increase the revenue from this renewable energy certificate source even further.

Some states have provided funding for wind farm development and some local governments have provided favorable property tax treatment. However, not all energy companies have been persuaded by government incentives to invest in wind energy. Exxon-Mobil, the largest company in the world, has not invested in wind energy because it prefers not to invest in businesses that rely on government subsidies to earn a profit.[4]

Over thirty states initiated deregulation of their electric systems. Deregulation is intended to foster competition and to encourage alternative sources of energy such as wind. States differ in their approaches and progress towards deregulation. One approach is the separation of generation, transmission and distribution. The customer can choose a generation supplier.

Some customers have eagerly signed up for energy produced by wind.[5] One observation about companies like Tom's of Maine, Toyota Motor Company and the Aspen Skiing Company that have made a commitment to green energy is the belief that such a commitment springs from ethics, not economics because, "... it simply costs more ..." (see [8]).

5. Technology improvements

Technology advances in wind energy have been dramatic, reducing costs from 30 cents per kWh in 1980 to the 3–5 cent range today. Power rating of the largest turbines has increased from 55 kW in 1980 to 4.5 MW in 2005. Although turbines larger than 2 MW are available, clustering 100 of them together for 200 MW is generally at the upper limit of what transmission interconnection to the grid can allow without costly upgrades. Consequently, the average new utility scale wind farm is typically in the 150 MW range. However, there are currently four wind farms in the 200–300 MW range. FPL Energy dedicated the world's largest wind farm in October 2006 near Abilene, Texas. The Horse Hollow Wind Energy Center has 735 MW of installed capacity and spans 47,000 acres.[6]

Size matters when producing electricity with wind. Tall towers, some over 400 ft high, can raise turbines to take advantage of stronger and less turbulent winds at high elevations. New materials such as E-glass/polyester allow blade lengths of 150 ft compared to 15 ft in 1980. This is significant because a wind turbine's capability to generate electricity increases by the square of the blade length.

Locating wind turbines in the right place is important because the energy produced by a wind turbine is proportional to the cube of the wind speed. For example, the potential of a wind turbine located at a site with an average wind speed of 15 mph versus one located at a site where the average wind speed is 10 mph can produce 238% more electricity.

The percentage of time a turbine can be in use during the 8760 h (365×24) of the year (i.e., the turbine utilization rate) has increased from 36–38% to 40–43% at the best sites. Modern turbines can operate at lower wind speeds more efficiently than older models. Furthermore, they can operate at wind speeds up to 50 mph, wind speeds that would have caused older models to be shut down or to fail.

Improved technology has made wind energy more cost competitive by bringing its cost down, but dramatic increases in

[3] American Wind Energy Association, "Energy Department, Wind Industry Join to Create Action Plan to Realize National Wind Vision of 20% Electricity from Wind," http://www.awea.org.html (accessed June 5, 2006).

[4] Ed Galante, retired Senior Vice President Exxon-Mobil and now Executive in Residence at the College of Business, Northeastern University, Boson, MA in a speech at the College, November 16, 2006.

[5] For example, Tom's of Maine, the maker of natural toothpaste and personal care products, has arranged to buy the equivalent of all its electricity from a Nebraska wind farm "Tom's of Maine to buy power from Nebraska wind farm," *Boston Globe*, February 10, 2006.

[6] FPL Energy, http://www.fplenergy.com.html.

the cost of oil and natural gas have also made wind energy more competitive. Some experts argue that if environmental and health costs caused by electricity generation using fossil fuels such as coal are included, the cost of those sources of energy is 50–100% higher than their nominal costs [9].

6. Environmental and social concerns

Although wind energy is considered to be sustainable from an environmental point of view, it is not without its critics because of environmental and social concerns. Locations with the best wind currents sometimes coincide with migratory paths of birds. The annual body count at a 50 square mile wind farm in the Diablo Mountains between San Francisco and the agricultural Central Valley in California is estimated around 5000 per year including endangered species [10]. One rejoinder by proponents of wind energy is statistics about many thousands of birds killed by oil spills.

Visual pollution might detract from pristine views or hinder tourism. For example, the former director of the Massachusetts Technology Collaborative, an organization that funds alternative energy projects, believes the biggest problem the trust faces in successfully funding wind energy projects is NIMBY (not-in-my-backyard) opposition.[7]

A recent moratorium was placed on the construction of some wind farms in the Mid-west by the Defense Department so that they could investigate national security concerns that wind farms might interfere with the operation of military radar systems. Furthermore, opponents of offshore sites are concerned they might disrupt boating, fishing and shipping. Others wonder about how to handle the issue of placing private facilities on public property.

A multi-year debate over the proposed Cape Wind project in Nantucket Sound off the coast of Cape Cod in Massachusetts illustrates the many problems of siting large wind farms in some parts of the country [11]. Cape Wind is a 24 square mile offshore wind farm proposed by a private entrepreneur for Nantucket Sound where the average wind speed is a desirable 17 knots. It could provide two thirds of the electricity for Cape Cod and the islands of Nantucket and Martha's Vineyard, generating an amount of electricity similar to the amount produced by a typical nuclear plant. The Cape Wind project would consist of 130, 3.6 MW turbines located on top of towers standing in excess of 400 ft high, which is taller than the Statue of Liberty.

The long list of those opposing the project included a *Who's Who* in Massachusetts in 2006. Environmental groups are well organized, well funded and almost unanimous in their vehement opposition to the Cape Wind project. Another voice opposing the project is one that is familiar with wind, the winner of the 1992 America's Cup, William Koch, founder and president of Oxbow Corporation and co-chairman of the Alliance to Protect Nantucket Sound. His analysis concludes that because of high capital and maintenance costs at the unfriendly offshore site, the project is a bad financial decision for investors even after hundreds of millions of dollars of government subsidies.[8]

7. Financial economics

Exhibit 1 contains financial information about a typical onshore utility scale wind farm (see [12]). The Net Present Value (NPV) of an investment using those key inputs as a base case is \$46.6 million and an IRR of 11%. Exhibit 2 shows the calculations. Both metrics, which include the benefits of the production tax credit, indicate the investment is worthwhile, with a modest margin of safety.

The positive NPV and an IRR of 11% would allow the company making the investment to cover all of its costs including a 7% pretax cost of debt and a 15% return to shareholders if the project were financed with 40% debt and 60% equity. Assuming a 40% tax rate this is illustrated as follows: $7\%(1-0.4)\times 0.4 + 15\% \times 0.6 = 11\%$. The rush to invest in wind farms suggests that an annual return of approximately 15% is an attractive risk adjusted rate of return to compensate investors for the risks involved.

It is interesting to note that if the PTC was only 1 cent per kWh versus 1.9 cents, the investment would still breakeven. All costs would be covered including the cost of capital.

Exhibit 1
Wind farm financial parameters

Capital cost	\$1600 per kW
Turbine capacity	2.0 MW
Number of turbines	100
Percentage of 8760 (365×24) total annual hours in use	40%
Project life study period with zero net salvage	15 years
Depreciation for tax purposes	5-year MACRS depreciation rates of 20%, 32%, 19%, 12%, 12% and 5% in years 1–6. Straight-line method was used for book reporting
Operating and maintenance expense	\$0.005 per kWh
Escalation of O&M expense	2% per year
Rate (price) received	\$0.040 per kWh
Rate escalation	1% per year
Tax rate	40%
Federal tax credit (PTC) for first 10 years	\$0.019 per kWh
Increase in PTC tied to GDP deflator	0.03
State renewable energy credit where available	\$0.005 per kWh
Weighted average cost of capital (WACC)	8%

Source: Director of Wind Operations at a large mid-western utility who wishes to remain anonymous. *Notes*: Capital Cost includes all costs of preliminary studies, land, construction, turbines, other equipment, and transmission lines to connect to the grid. Turbines might last longer than 15–20 years, but by then major equipment replacement such as blades and drive trains might have to be done. The 4.0 cents per kWh rate received is primarily an energy charge. However, some part of it could be for capacity that depends on supply and demand in the region. For example the capacity charge could be low when excess capacity exists, and run up if the system is short of capacity. Wind has a relatively low capacity value when compared to thermal generation due to wind's intermittent generation profile. The PTC assumes the company has enough tax liability to take advantage of the credit. This would probably be true for large companies where wind energy operations are a small part of their overall business, but it could be a problem for small start-up wind developers who are unable to partner with larger firms. Furthermore, at the present time there is no market for unusable wind energy production tax credits. Where state renewable energy credits are available, they are typically reflected in the rate received by producers of wind energy. However, they are shown as a separate line item above. The 8% Weighted Average Cost of Capital assumes a pretax cost of debt of 7%; cost of equity of 10.6% estimated using the Capital Asset Pricing Model and based on Beta coefficient = 1.1, risk free rate of 4%, and an overall return on the stock market of 10%; and financing raised with 40% debt and 60% equity. However, the cost of capital could be higher if the wind project is perceived more risky than the average risk investment of the parent utility or if funding were being provided by organizations such as private equity firms that require higher returns in the 15–20% range or smaller firms independent of a larger utility.

8. Financial viability without the production tax credit

Using the base case assumptions, if the Production Tax Credit were completely eliminated, NPV becomes negative and IRR falls below the cost of capital. Investors would find it difficult to earn the minimum return necessary to compensate for the risks

[7] "Cash for Clean Energy," *Boston Globe*, October 23, 2006.
[8] *Wall Street Journal*, May 22, 2006.

Exhibit 2
The exhibit presents the cashflow computations for the first 15 years of the project under the scenario presented in Exhibit 1

	Year															
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Capital cost	320.0															
Annual kWh prod.		700.8	700.8	700.8	700.8	700.8	700.8	700.8	700.8	700.8	700.8	700.8	700.8	700.8	700.8	700.8
Oper. Revenue		28.0	28.3	28.6	28.9	29.2	29.5	29.8	30.1	30.4	30.7	31.0	31.3	31.6	31.9	32.2
O&M		3.5	3.6	3.6	3.7	3.8	3.9	3.9	4.0	4.1	4.2	4.3	4.4	4.4	4.5	4.6
Depreciation		64.0	102.4	60.8	38.4	38.4	16.0									
Profit before tax		−39.5	−77.7	−35.9	−13.2	−13.0	9.6	25.8	26.0	26.2	26.5	26.7	26.9	27.1	27.4	27.6
Tax		−15.8	−31.1	−14.3	−5.3	−5.2	3.8	10.3	10.4	10.5	10.6	10.7	10.8	10.9	10.9	11.0
Profit after tax w/out interest		−23.7	−46.6	−21.5	−7.9	−7.8	5.8	15.5	15.6	15.7	15.9	16.0	16.2	16.3	16.4	16.6
Fed credit		13.3	13.7	14.1	14.5	15.0	15.4	15.9	16.4	16.9	17.4					
State credit		3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Net profit with credits and without interest		−6.9	−29.4	−3.9	10.1	10.7	24.7	34.9	35.5	36.1	36.8	19.5	19.7	19.8	19.9	20.1
Net cash flow	−320.0	57.1	73.0	56.9	48.5	49.1	40.7	34.9	35.5	36.1	36.8	19.5	19.7	19.8	19.9	20.1
WACC									8.00% per year							
NPV									46.59 ($ mn.)							
IRR									11.01%							
Payback period									5.87 years							
Discounted payback									9.41 years							

All figures are in $ mn.

involved. However, if Capital Cost declines and/or the Utilization Rate increases, wind farm investments could break even without the PTC. Capital Cost and Utilization Rate are two variables that could likely change in a favorable way and have a material impact on the financial viability of wind investments.

Exhibit 3 shows combinations of these two key inputs that could make investments financially sound without the PTC. As can be seen from Exhibit 3, the tradeoff is that a decrease of $100 in the capital cost per kW has the same effect as a 3.33% increase in the utilization rate. Under the assumption of a capital cost equal to $1600 per kW in the base case, the required utilization rate for a breakeven NPV is 53.3%. However, a lower capital cost of $1200 makes investments profitable without the PTC if the utilization rate is 40%. Other combinations of capital cost and utilization rate that require less dramatic changes, such as $1400 and 47% provide for profitable investment without the PTC.

Future technology improvements can reduce capital costs, as has been the historical trend in this dynamic industry. If capital cost declines, investments in wind energy, as demonstrated by this research, can become profitable without the federal credit. Furthermore, upward pressure on capital cost may abate as supply and demand come back into balance. Some of the recent capital cost inflation has resulted from supply bottlenecks resulting from a rush to invest before the expiration of the Federal tax credit. An example of the bottleneck and short supply that exists is the reported situation at General Electric. In 2005, GE sold 2400 megawatts of wind turbines worldwide, equivalent to nine fossil fuel power plants, and has nearly sold out of wind turbines through 2008 [13]. Furthermore, some large multinationals such as the Royal Dutch Shell Group and BP PLC are bidding up the cost of land by leasing large tracts and planning some of the largest wind farms in the world [14].

Exhibit 3
Combinations of utilization rates and capital cost per kW

Utilization rate (%)	Capital expenditure ($/kW)
33.32	1000
36.65	1100
39.98	1200
43.31	1300
46.64	1400
49.97	1500
53.31	1600
56.64	1700
59.97	1800
63.30	1900
66.63	2000

The table shows combinations of Utilization Rate in % per year and Capital Cost in $ per kW that result in a Break-even NPV without the PTC. All the remaining inputs for these computations are fixed at values used in the base case scenario.

Another potentially favorable factor for the financial economics of wind energy is that technology improvements can increase the utilization rate. This has been the historical trend in this industry. Beyond technology improvements, public policy that allows wind farms to locate at sites with the most steady and reliable wind conditions can enhance the utilization rate.

Furthermore, as the cost of sources of energy such as oil and natural gas become more expensive, wind energy becomes more competitive. If the price received for wind energy produced by wind farms reaches 5.4 cents per kWh (versus the 4.0 cents assumed in our base case), investments in wind energy break even without the PTC. It is interesting to realize, for example, that through May of 2007, the average wholesale price paid for electricity on the Intercontinental Exchange that serves the Mid-west U.S. averaged 5.91 cents per kWh.[9] If such a price level continues in the future, positive financial returns for wind farm developers can be more certain without the federal credit.

Clearly, the wind energy industry is on a short path to become financially self-sustaining without the federal production tax credit. This is happening because of the convergence of improved technology, greater efficiency, and rising costs of competing sources such as oil and natural gas. Consequently, wind energy can soon provide the best of both worlds. It is already sustainable from an environmental perspective and it is becoming sustainable financially. In short, those investing in wind energy will be able *to do well by doing good*, and achieve dual sustainability. Perhaps dual sustainability is true sustainability.

9. Policy implications

Thirty years ago private investment in wind energy was considered uneconomic, in part, because private investors could not capture social benefits that would be reaped by society from this clean and renewable energy source. It was a classic example

[9] Energy Information Administration, *Official Energy Statistics from the U.S. Government*, http://www.eia.doe.gov.html.

where public policy was needed to foster development for the good of society. This was accomplished in several ways, including setting national goals for renewable energy, eliminating barriers to entry in an industry once dominated by large public utilities wedded to traditional technologies, and providing financial incentives such as the generous Production Tax Credit.

Our research findings reported in this article have several important public policy implications that should be considered. Although it appears technology improvements can eventually make investments in wind farms economically viable without the Production Tax Credit, eliminating the credit entirely as is now planned for December 2008 might be unwise. A better course of action for public policy could be to phase out the PTC over time. Our findings are that a PTC of 1 cent (versus the current 1.9 cents) would still allow investors to breakeven and earn a normal profit. Consequently, a safer policy would be to reduce the credit to 1 cent rather than eliminate it entirely. This would avoid disruption and interruption of progress that has occurred in the past when Congress delayed renewing the credit and private investments in wind farms came to a halt.

Secondly, since lowering capital cost is one of the keys to ensuring the financial viability of a private wind farm investment, a subsidy for capital expenditure rather than a production tax credit could be considered. If a subsidy were paid equal to $400 per kW of capacity, which brings the effective capital cost down to $1200 per kW from $1600 per kW, this would be sufficient to make the investment breakeven without the PTC. In our example this would cost the government $80 million for the subsidy per wind farm. However, this is significantly less than the $152.6 million in production tax credits over 10 years in the example. This would save the government $72.6 million per wind farm, nearly enough to subsidize another wind farm.

Furthermore, this would create a greater incentive for smaller, entrepreneurial start-up firms which might not be able to take advantage of the Production Tax Credit because they lack sufficient taxable earnings and tax liabilities against which to use the full PTC in their early years of operation.

Thirdly, one size does not fit all. Costs differ by geographic region. The subsidy could be tailored to reflect differing costs to encourage locating wind farms throughout the country, on-shore and offshore, so that wind energy is not just be concentrated in a few areas.

Fourth, siting policy needs to be reviewed. Locating wind farms in the right places is critically important to achieve high levels of usage. The 53% usage rate that allows private investment to breakeven financially without the PTC requires locating plants where the wind is strong and steady. A major impediment to siting wind farms is local opposition, sometimes described as NIMBY (not in my back yard). The delay caused by the 6-year debate over the Cape Wind project in Massachusetts described above is a case in point. In stark contrast to the political wrangling that has impeded a decision on this first U.S. offshore wind farm, the UK has just announced a plan to generate enough electricity from offshore wind farms to power every home in that country by 2020.[10] The objective is to achieve energy self-sufficiency in Britain.

Federal authorities in the U.S. may want to consider usurping siting decisions from state and local jurisdictions. Otherwise, wind farm development could be severely constrained and delayed.

10. Conclusion

The financial economics of wind energy has changed dramatically. In addition to being sustainable from an environmental perspective, it is becoming self-sustaining financially. This *dual sustainability* suggests it is time to reevaluate public policy towards wind energy. Some alternatives that might be more effective and efficient are enumerated in this article for consideration. However, they do not exhaust the list of possibilities for enlightened public policy towards this magnificent energy source.

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